A89-52844 Nonlinear theory of brittle fracture (K nelineinoi teorii khrupkogo razrusheniia). MR. LE KHAN CHAU, *Akademiia Nauk SSSR, Doklady* (ISSN 0002-3264), Vol. 307, No. 2, 1989, pp. 321–323. 8 Refs.

A mathematical model is proposed which describes the brittle fracture of a nonlinearly elastic body that does not have any initial cracks. The main idea of the approach is based on the following variational principle: the full energy of an elastic body attains a stationary value only in the equilibrium configuration. The inclusion of discontinuous configurations modeling a body with cracks into the set of all possible configurations makes it possible to apply this principle to the fracture theory. Thus, the development of a mathematical model of a fracturing body is reduced to the specification of its full energy for all possible configurations including the discontinuous ones.

A89-50848 A study of the effect of microcracks on fracture kinetics and shock wave structure in metals (Issledovanie vliianiia mikrotreshchin na kinetiku razrusheniia i strukturu udarnykh voln v metallakh). O. B. NAIMARK and V. V. BELIAEV, *Problemy Prochnosti* (ISSN 0556-171X), July 1989, pp. 46–53. 32 Refs.

The characteristics of formation of stress wave fronts in solids with microcracks are analyzed using a deformation model. It is shown that the splitting of a shock wave into an elastic precursor and a plastic wave is a result of a kinetic transition with respect to a parameter characterizing the microcrack orientation mode. The kinetics of the disperse-microscopic fracture transition is investigated. The relationship between the self-similarity of the fully developed fracture process and the dynamic branch spall effect is discussed.

A89-48905 Microfracture localization in a fiber composite (Lokalizatsiia mikrorazrushenii v voloknistom kompozite). V. S. KRIVOBODROV and G. N. GUBANOVA, *Mekhanika Kompozitnykh Materialov* (ISSN 0203-1272), May–June 1989, pp. 437–443. 5 Refs.

A dimensionless microfracture localization parameter is introduced which characterizes the homogeneity of microfracture accumulation within a fiber composite. It is shown that this parameter can be determined experimentally from the data on the acoustic emission of the signal sources and theoretical calculations based on a fracture model. Results obtained for a carbon fiber composite are presented as an example.

A89-42412 Estimation of the fracture of composite plates with openings (Otsenka razrusheniia plastin iz kompozitnykh materialov s otverstiiami). B. D. ANNIN and V. N. MAKSIMENKO, *Mekhanika Kompozitnykh Materialov* (ISSN 0203-1272), Mar.–Apr. 1989, pp. 284–290. 10 Refs.

A method is proposed for estimating the ultimate strength of composite materials with free and pin-loaded holes. The approach proposed here is based on the integral equation method and principles of linear fracture mechanics. The advantages of the method are demonstrated by comparing results obtained for several problems with finite element solutions and experimental data.

A90-30394 Modeling of crack formation processes and fracture of multilayer composites—A vector model of a composite material (Modeliuvannia protsesiv trishchinoutvorennia i ruinuvannia bagatosharovikh kompozitsiinikh materialiv—Vektorna model' kompozitsiinogo materialu). M. V. DELIAVS'KII, *Fiziko-Khimicheskaia Mekhanika Materialov* (ISSN 0430-6252), Vol. 26, Jan.-Feb. 1990, pp. 22–26. 6 Refs.

The fracture mechanism of compressed panels under conditions of creep is determined based on an analysis of test data, and a deformation criterion is proposed. It is shown that prior creep significantly reduces the load-bearing capacity of a panel during subsequent short-term loading. An explanation is presented for the loss of stability of thin-walled panels and rods under creep.

A89-48906 Relation between interphase interaction and fracture surface characteristics of fiber-reinforced thermoplastics (Vzaimosviaz' mezhfaznogo vzaimodeistviia s kharakteristikami poverkhnostei razrusheniia voloknisto-armirovannykh termoplastov). A. I. SVIRIDENOK, A. IA. GRIGOR'EV, V. V. MESHKOV, and T. K. SIROTINA, *Mekhanika Kompozitnykh Materialov* (ISSN 0203-1272), May–June 1989, pp. 444–447. 8 Refs.

A method for studying fracture surfaces is proposed which is based on the selective estimation of surface irregularity parameters at different scales. The characteristics of phase interactions are found to correlate with the statistical characteristics of the fracture surface. The correlations established here can be used for determining the structure of materials and for increasing the strength of materials by optimizing the statistical characteristics of fracture surfaces.

A89-42484 Surface effect on the brittle strength of solid bodies (Vliianie poverkhnosti na khrupkuiu prochnost' tverdykh tel). P. K. KHODZHER, *PMTF—Zhurnal Prikladnoi Mekhaniki i Tekhnicheskoi Fiziki* (ISSN 0044-4626), Mar.–Apr. 1989, pp. 175–179. 12 Refs.

Surface defects have been shown to have a significant effect on the brittle strength of solid specimens. In the present work, the risk factors associated with bulk and surface defects are determined, and the fundamental relationship between their parameters and the size of the body is established. The neutralization of surface defects is also considered.

A89-42411 Effect of the degree of reinforcement on the strength and fracture characteristics of unidirectional fiber composites (Vliianie stepeni armirovaniia na prochnost' i kharakter razrusheniia odnonapravlennykh voloknitov). A. F. ERMOLENKO and V. D. PROTASOV, *Mekhanika Kompozitnykh Materialov* (ISSN 0203-1272), Mar.–Apr. 1989, pp. 276–283. 5 Refs.

A study is made of the possibility of identifying mechanical processes from their acoustic images recorded in a limited frequency range. The approach proposed here is based on the comparison of the spectra in terms of the mean energy and median frequency. Acoustic emission scattering ellipses are plotted for fracture mechanisms of different types. A process identification criterion is proposed.

A89-35664 Evaluation of the fracture toughness of a material based on the deformation diagram (Ob otsenke treshchinostoikosti materiala na osnove diagrammy deformirovaniia). L. P. KHOROSHUN, *Prikladnaia Mekhanika* (ISSN 0032-8243), Vol. 25, Feb. 1989, pp. 59–66. 7 Refs.

A new criterion for evaluating the brittleness and fracture toughness of materials is proposed which is based on a piecewise linear approximation of the deformation diagram. The plane problem of the fracture of a body with a cylindrical cavity under uniform biaxial tension is analyzed as an example. The correlation between the fracture toughness criterion proposed here and the fracture toughness of aluminum alloys and steels is examined.

A89-34087 Structural characteristics and strength of zirconium reinforced by tungsten and molybdenum fibers (Osobennosti struktury i prochnost' tsirkoniia, armirovannogo vol'framovymi i molibdenovymi voloknami). L. R. VISHNIAKOV, V. P. MOROZ, V. A. PISARENKO, A. B. SAMELIUK, *Poroshkovaia Metallurgiia* (ISSN 0032-4795), Feb. 1989, pp. 76–79. 10 Refs.

A study is made of the structure and fracture characteristics of a zirconium-matrix composite reinforced by 80-100-micron-diameter tungsten and molybdenum fibers (volume fraction, 25-30 percent). It is shown that, at high temperatures (950 C), the composite retains its high strength despite the interaction between fibers and the matrix. The high strength and ductility of the composite makes it an attractive structural material.

Japanese Aerospace Literature This month: *Fracture Mechanics*

A90-46059 A method of fatigue life prediction for composite materials - In case of prediction based on the extension mode. MASARU ZAKO, TETSUYA TSUJIKAMI, and HIROYUKI YOSHIZAWA, *Japan Society of Materials Science Journal* (ISSN 0514-5163), Vol. 39, June 1990, pp. 701–705.

A technique for predicting the fatigue life of laminated composites is developed on the basis of linear fracture mechanics and evaluated experimentally by means of cyclic tests on (+/-30)s, (+/-45)s, and (+/-60)s CFRP plates. The derivation of the governing equations is outlined, and the theoretical predictions are compared with measurement data in extensive tables and graphs. Good general agreement is demonstrated in most cases, and it is shown that fatigue life depends mainly on (1) the ultimate tensile and shear strength of the matrix and (2) the initial crack length (estimated from data on the size of voids and defects). Poor prediction accuracy is obtained in the case of the (+/-30)s laminates in the long-life regime, where fracture involves a combination of shear and tensile modes.

A90-33684 Stress intensity factor analysis by combination of boundary element and finite element methods. N. MIYAZAKI, T. IKEDA, and T. MUNAKATA, *Engineering Fracture Mechanics* (ISSN 0013-7944), Vol. 36, No. 1, 1990, pp. 61–70. 15 Refs.

A version of the boundary element method is proposed for calculating the stress intensity factors of two-dimensional crack problems including mixed mode ones. In this method, finite elements are only allocated around a crack tip, and boundary elements are used to discretize the rest of a structure. The virtual crack extension method is applied to the finite elements to obtain the stress intensity factors, together with the method for the separation of displacement components into mode I and mode II for mixed mode crack problems. The analyses are performed not only for single mode crack problems but also for mixed mode crack problems. It is found that large-sized finite elements around the crack tip can be used for straight crack problems and to select the crack extension value from the wide range of values.

A91-22397 Observations of microstructure and fracture surface of stainless steels fatigued at cryogenic temperatures. KAZUMUNE KATAGIRI, TOICHI OKADA, MASAHIRO TSUJI, KIYOTSUGU OHJI, RIKURO OGAWA et al., *Japan Society of Materials Science Journal* (ISSN 0514-5163), Vol. 39, Nov. 1990, pp. 1563–1569. 14 Refs.

Measurements of fatigue crack growth characteristics at room and liquid nitrogen temperatures as well as observations of microstructure and fracture surface topography of metastable 304L were carried out. The results obtained were compared with those for stable austenitic stainless steels (310 and high-Mn stainless steel). The effective stress range ratio of 304L steel at liquid nitrogen temperature was larger than that at room temperature or that of 310 steel. The blocks of alpha prime martensite transformed from austenite via epsilon martensite were observed in the close neighborhood of cracks in 304L steel, whereas no alpha prime was found in the high-Mn stainless steel. The fracture surface of 304L steel at liquid nitrogen temperature was smooth and flat. Based on these observations, the fatigue crack growth mechanisms in stainless steels at cryogenic temperatures are briefly discussed with emphasis on the crack closure.

A91-16093 Tensile strength and fracture defects expanded by subcritical crack growth of silicon nitride at high temperatures. T. OHJI, Y. YAMAUCHI, W. KANEMATSU, and S. ITO, *Journal of Materials Science Letters* (ISSN 0261-8028), Vol. 9, Nov. 1990, pp. 1266–1268. 9 Refs.

The effect of fracture defects expanded by subcritical crack growth (SCG) in silicon nitride at 1200 C on the strength properties of the material was investigated using SEM and tensile test measurements. In a fractographic study of internally fractured specimens at 1200 C, a wake of SCG was clearly observed as a circular whitish area. The values of Kc were estimated for each expanded crack and plotted against the crack radius. The increments of Kc showed good agreement with the previously investigated R-curve behavior of hot-pressed silicon nitride in the temperature range 1140-1260 C.

A91-15120 Acoustic Emission (AE) signals and fracture in SiC-fiber reinforced aluminum after applying cyclic deformation. AKIRA OKADA, and SHIN-ICHI JIM KITAGAWA, (ISSN 0916-1821), Vol. 31, Sept. 1990, pp. 772-777. 13 Refs.

The correlation between the mechanical property change and the AE signal emitted during the 3-point bending deformation was investigated for the SiC-fiber reinforced aluminum after applying cyclic deformation. AE signals reflect the change in fracture behavior due to the change in bonding between SiC and the Al matrix, and the introduction of defects, by cyclic deformation. The spectrum at a higher frequency became stronger in the specimens degraded by applying the fatigue history and in these specimens preformed SiC-Al wires were observed with SEM to split into several thinner bunches. Almost the whole number of AE events was observed just before the occurrence of rupture in the specimens without cyclic deformation, while in the specimens with cyclic deformation, the number of the AE signals increased continuously over a wide stress range with increasing applied stress from a relatively smaller applied stress until the specimen ruptured.

A91-13084 Fracture behavior and its relation to critical current of silver-sheathed Ba2YCu3O(7-x) superconducting composite wires and tapes. SHOJIRO OCHIAI, KENJI HAYASHI, and KOZO OSAMURA, *Journal of Materials Science* (ISSN 0022-2461), Vol. 25, Aug. 1990, pp. 3467–3474. 12 Refs.

Silver-sheathed Ba2YCu3O(7-x) superconducting composite wires and tapes were prepared by rolling, drawing, swaging and pressing methods. The fracture behavior and its influence on critical current at 0T at 77 K of the Ba2YCu3O(7-x) were investigated. The oxide was found to show multiple fracture under applied tensile stress, and the critical current density and tensile strength of the oxide in the rolled, swaged and pressed samples were higher than those in the drawn samples. When the working amount was high, the current density and the strength of the oxide were found to become high. Within the present conditions, there was a correlation between critical current density and cracking stress: the higher the cracking stress, the higher the critical current density became. The cracking stress of the present oxide was determined to be 50 MPa at most, being far lower than that of the Nb3Sn compound (800 to 2000 MPa). The critical current density of the rolled, swaged and pressed samples was reduced rapidly when exerted stress on the oxide exceeded the cracking stress, while the reduction in the drawn samples occurred gradually. A strong dependence of the critical current, as a function of applied stress and cracking stress of the oxide, on the measured portion due to scatter in the size of defects contained in the oxide, was found.

A90-35967 Fabrication of whisker/glass composites from hydrothermally oxidized Si3N4 whisker. MASAHIRO YOSHIMURA, TATSUO NOMA, NAOYA OGASAWARA, and SHIGEYUKI SOMIYA, *Proceedings of the 1st MRS International Meeting on Advanced Materials,* Tokyo, Japan, May 31–June 3, 1988, Vol. 5 (A90-35926 15-27). Pittsburgh, PA, Materials Research Society, 1989, pp. 497–502. 7 Refs.

The fabrication of Si3N4 whisker/SiO2 glass composites by hot-pressing of hydrothermally oxidized Si3N4 whiskers is reported. Almost full density was obtained by hot-pressing at 1200 C under 35 MPa for four hours. Fracture toughness measured by Vickers indentation method was 1.4-2.5 MPa sq rt m and decreased with increasing cristobalite content.

A91-13001 Fracture mechanics of interfaces. MASAYUKI TOYA, *JSME International Journal, Series I* (ISSN 0914-8809), Vol. 33, Oct. 1990, pp. 413-424. 56 Refs.

This review addresses fracture mechanics of interfaces as related to the process of interfacial crack growth between dissimilar elastic materials. Methods of solution of interfacial crack problems are presented. The concepts of complex stress intensity factors and energy release rate are then discussed. It is suggested that energy release rate, rather than stress intensity factors, is a more appropriate parameter for characterizing the occurrence of interfacial fracture. Topics on the competition between crack penetration and deflection at an interface, delamination of laminated beams, and fracture models for fiber-reinforced composite materials relevant to the debonding of the fiber-matrix interface are reviewed with an emphasis on the energy release rate approach.

A90-50393 Mixed mode fracture criteria on adhesive joints. RYOJI YUUKI, NAM-YONG CHUNG, HARUO ISHIKAWA, and SHIZUKA NAKANO, *Japan Society of Materials Science Journal* (ISSN 0514-5163), Vol. 39, Aug. 1990, pp. 1095–1100. 13 Refs.

Adhesive joint specimens, with acryl plate and epoxy plate used as adherends and Cemedine 1500 and EP-007 used as adhesives, were tested under static and fatigue conditions. The energy release rates GI and GII were analyzed by the finite element and modified virtual crack extension methods. The fracture toughness results yield a mixed mode fracture criterion which can be characterized in terms of GI and GII. It is found that the fatigue crack growth rate in various adhesive joints can be adequately characterized by the total energy release rate.

A90-50391 Evaluation of fracture toughness and resistance of high strength graphite. HIDEO KOBAYASHI, YOSHIO ARAI, TATSUO OKU, and TOORU ARAKI, *Japan Society of Materials Science Journal* (ISSN 0514-5163), Vol. 39, Aug. 1990, pp. 1076–1081. 6 Refs.

The fracture toughness and fracture resistance characteristics of three high-strength graphite materials, IG-11, IG-110, and IG-110U, were examined as a function of the specimen size and the initial notch. The effect of temperature on the fracture toughness was also examined at temperatures ranging from room temperature to 820 C in vacuum and in air. The graphite materials studied exhibit a characteristic R-curve behavior whereby the fracture resistance increases during the initial stage of crack extension near the initial notch tip, levels off at the intermediate stage, and then decreases during the final stage. The true fracture resistance is shown to be constant and equal the fracture toughness.

A90-46139 Effects of temperature and grain size on deformation and fracture in recrystallized Ni3Al doped with boron. M. S. KIM, S. HANADA, S. WATANABE, and O. IZUMI, *Journal of Materials Science* (ISSN 0022-2461), Vol. 25, March 1990, pp. 1590–1597. 23 Refs.

Tensile tests have been conducted at temperatures of up to 973 K, in order to ascertain temperature and grain size effects on the deformation and fracture behaviors of B-doped Ni3Al as a function of grain sizes in the 1.6-105.0 micron range. While for coarse-grained specimens, a rapid drop in elongation occurred with increasing temperature, the intermediate and fine grained specimens did not show such a marked decrease in elongation at elevated temperature, respectively exhibiting ductile intergranular fracture and cavitation fracture; at low temperatures, the respective fracture modes were slant-type and cup-cone type. The suppression of most high-temperature embrittlement in intermediate-grained specimens is seen as due to the slow propagation of a crack formed by grain-boundary sliding, because of stress relaxation by dynamic recrystallization and plastic deformation.

A90-43809 Dependence of energy-absorbing capacity on mechanical properties under penetration. KEN KAMINISHI, SHUNICHI KAWANO, MOTOHARU TANEDA, and TOSHIHIRO NANBA, *JSME International Journal, Series I* (ISSN 0914-8809), Vol. 33, July 1990, pp. 297–302. 11 Refs.

The effects of mechanical properties involving fracture toughness on the energy-absorbing capacity are studied. Quasistatic and dynamic penetration tests are performed on 1.0 mm thick circular sheets of extra super duralumin, corrosion-resisting aluminum alloy, and cold-rolled carbon steel. Yield point, tensile strength, elongation, tearing modulus, crack growth and length, and impact velocity are measured. The relations between impact velocity and energy of the ballistic limit and total crack length and energy-absorbing capacity are analyzed. It is noted that fracture toughness, yield point, and ultimate strength all have the same influence on the ballistic limit energy.

A90-39620 Foreign object damage resistance of silicon nitride and silicon carbide. HIDEYOSHI TSURUTA, MASAAKI MASUDA, TAKAO SOMA, and MINORU MATSUI, *American Ceramic Society Journal* (ISSN 0002-7820), Vol. 73, June 1990, pp. 1714–1718. 10 Refs.

To clarify the foreign object damage resistance of ceramics, chipping fracture mode and flexural fracture mode were investigated using several types of Si3N4 and SiC. The critical velocity which is the threshold impact velocity of the projectile for chipping fracture and flexural fracture was determined. The critical velocity of the chipping fracture mode is explained as a function of K(Ic) exp 5/2(a exp -5/4), and depends on the hardness and the shape of the projectile. The critical velocity of the flexural fracture mode is explained as a function of sigma(c) exp 5/6(t exp 5/3). The mechanisms of impact damage are discussed.

A90-46084 Short and long fatigue crack growth in a SiC reinforced aluminum alloy. SHINJI KUMAI, JULIA E. KING, and JOHN F. KNOTT, *Fatigue and Fracture of Engineering Materials and Structures* (ISSN 8756-758X), Vol. 13, No. 5, 1990, pp. 511–524. Research supported by the British Gas Corp. 21 Refs.

Fatigue crack growth behavior in a 15 wt pct SiC particulate reinforced 6061 aluminum alloy has been examined using precracked specimens. Crack initiation and early growth of fatigue cracks in smooth specimens has also been investigated using the technique of periodic replication. The composite contained a bimodal distribution of SiC particle sizes, and detailed attention was paid to interactions between the SiC particles and the growing fatigue-crack tip. At low stress intensity levels, the proportion of coarse SiC particles on the fatigue surfaces with much smaller than that on the metallographic sections, indicating that the fatigue crack tends to run through the matrix avoiding SiC particles. As the stress intensity level increases, the SiC particles ahead of the growing fatigue crack tip are fractured and the fatigue crack then links the fractured particles.

A90-41434 Experimental study of mixed mode stress intensity factors in rotating disk having the cracks by photoelasticity and caustic method. SUSUMA TAKAHASHI and TSUTOMU EZUMI, *Proceedings of the Seventh International Conference on Advances in Fracture Research* (A90-41276 18-39), Vol. 5, Mar. 1989, pp. 3283–3290. 14 Refs.

The mechanical behavior around a crack tip is analyzed for three different rotating speeds (1300, 1800, and 2100 rpm) and at different crack inclination angles and lengths for epoxy resin rotating disks. The behavior is analyzed by means of the photoelastic stress freezing method. The KII/KI ratio of the stress intensity factors (SIFs) is determined by using the angle of the isochromatic fringe loops near the crack tip. The two separate SIFs, KI and KII, are obtained from the isochromatic fringes of the mixed mode and are used to investigate the influence of KI and KII on fracture in rotating disks. There is favorable agreement of these experimental results with theoretical results. Attention is then given to the branching-crack phenomena which is observed for the mixed mode with complicated geometry. KI and KII are determined using the photoelastic method and the method of caustics. The interaction of branched cracks is discussed, along with comparisons of these experimental results with those of a single crack.

A90-41415 Time dependent and cycle dependent behavior of sintered silicon carbide and alumina ceramics. A. T. YOKOBORI JR., T. ADACHI, T. YOKOBORI, H. ABE, J. NAKAYAMA et al., *Proceedings of the Seventh International Conference on Advances in Fracture Research* (A90-41276 18-39), Vol. 4, Mar. 1989, pp. 2927–2936. 14 Refs.

Stress rate dependence of strength, static fatigue and cyclic fatigue were studied for sintered silicon carbide and alumina ceramics. The strength of silicon carbide decreases with increase of stress rate and is not affected by time-dependent mechanism or cycle-dependent mechanism. Fracture occurs at constant strain. On the other hand, the strength of alumina ceramics increases with increase of stress rate and is affected by time-dependent mechanism in the lower frequency range and by cycle-dependent mechanism at higher frequencies. The transition region from time dependent control to cycle dependent control is discussed.

A90-41325 Propagation and non-propagation of small fatigue cracks. KEISUKE TANAKA and YOSHIAKI AKINIWA, *Proceedings of the Seventh International Conference on Advances in Fracture Research* (A90-41276 18-39). Research supported by Kurata Research Grant. Vol. 2, Mar. 1989, pp. 869–887. 27 Refs.

The propagation and non-propagation of small fatigue cracks at the notch root were studied in the first part of the present paper. A resistance-curve method was proposed for predicting the growth threshold of mechanically short cracks on the basis of the experimental results on the development of crack closure. The effects of material, notch geometry, and mean stress on the growth threshold of short cracks and the notch fatigue strength were successfully predicted by the resistance-curve method. In the second part, the propagation behavior of small fatigue cracks in smooth specimens was examined. A micromechanical model of small crack growth was combined with statistical simulation of crack growth for life prediction. The fatigue failure diagram was constructed to judge the threshold condition for small crack growth.

A90-20341 Characteristics of strength and their relations to flaw size distribution in several ceramic materials. I—Static strength. JUNICHI KITAZUMI, YOSHIFUMI TANIGUCHI, TOSHIHIKO HOSHIDE, and TOSHIRO YAMADA, *Japan Society of Materials Science Journal* (ISSN 0514-5163), Vol. 38, Nov. 1989, pp. 1254–1260. 20 Refs.

The characteristics of static strength of several ceramic materials (including samples of Si3N4, partially stabilized zirconia, and 92 and 96 percent Al2O3) were investigated using three-point bending tests with a constant loading rate carried out in air at room temperature. In addition, the effects of specimen geometry and temperature on the strength of the Si3N4 material were investigated using ring compression tests at room temperature and at 1300 C. In the three-point bending tests, better fitness for the two-parameter Weibull distribution was found when data were correlated with the true fracture stress evaluated at the fracture point of the specimen, rather than the maximum nominal stress. The effect of specimen geometry on strength was found to be small. The fracture surface of the tested specimens was observed through SEM, and the strength values were correlated with the equivalent crack length, demonstrating that the strength decreases with decreasing flaw size.

A90-35930 Deformation and fracture of SiC studied by high resolution transmission electron microscopy. G. SASAKI, K. HIRAGA, M. HIRABAYASHI, T. HIRAI, and K. NIIHARA, *Proceedings of the 1st MRS International Meeting on Advanced Materials,* Tokyo, Japan, May 31–June 3, 1988, Vol. 5 (A90-35926 15-27). Pittsburgh, PA, Materials Research Society, 1989, pp. 25–30.

Mircostructures of chemically vapor deposited (CVD)-SiC and hot-pressed (HP)-SiC, which were deformed by indentation at room temperature, 1000, and 1300 C, were examined by high-resolution and ordinary transmission electron microscopy. In both the CVD-and HP-SiC deformed at the three temperatures, a number of stacking faults were observed around indentation. In CVD-SiC, cracks initiate from the corners of an indentation hole and propagate transgranularly parallel to the close-packed plane at all the indentation temperatures, but the propagation becomes less pronounced at higher temperatures. IN HP-SiC, on the other hand, cracks propagate intergranularly at high temperatures above 1000 C, and grain boundary fracture takes place. At high temperature, the deformed region around the indentation in HP-SiC is smaller than that in CVD-SiC.

A90-32380 Numerical simulation of initiation and early propagation of creep-fatigue small cracks based on a model of random fracture resistance of grain boundaries. R. OHTANI, T. KITAMURA, and N. TADA, *Structural design for elevated temperature environments—Creep, ratchet, fatigue, and fracture; Proceedings of the ASME/JSME Pressure Vessels and Piping Conference,* Honolulu, HI, July 23-27, 1989 (A90-32376 13-39). New York, American Society of Mechanical Engineers, 1989, pp. 123–127. 10 Refs.

This paper proposes a simple model of initiation and early propagation, under creep-fatigue condition, of small intergranular cracks, which is characterized by random fracture resistance of grain boundaries. Based on this model, a numerical calculation was performed for a smooth specimen of type-304 stainless steel subjected to the slow-fast strain cycle of 1-percent total strain range at 650 C in a vacuum. The result of this simulation on the crack density, the cumulative probability of crack length, and crack-propagation rates were found to coincide with experimental results.

A90-32370 The dynamic J integral (J-prime) and its use in finite element simulation of dynamic crack propagation. T. NISHIOKA, Y. TAKEMOTO, and R. MURAKAMI, *Dynamic fracture mechanics for the 1990's; Proceedings of the ASME/JSME Pressure Vessels and Piping Conference,* Honolulu, HI, July 23-27, 1989 (A90-32362 13-39). New York, American Society of Mechanical Engineers, 1989, pp. 117–125. 23 Refs.

Recent theoretical and computational studies of the dynamic J integral and moving finite element procedures are summarized. The invariance of the elastodynamic J integral with respect to the shape of an infinitesimal process zone is discussed. An asymptotic expression method for determining the mixed-mode stress intensity factors using path-independent integrals is examined, as is a moving finite element method aided by computerized symbolic manipulation. A concept of an element-controlling plane based on Lagrangean-element mapping for the simulation of dynamic crack curving is discussed.

A90-32364 Thermal shock fracture toughness of SiC. H. HOMMA, Y. KANTO, Y. NOBUTA, and E. FUKAMACHI, *Dynamic fracture mechanics for the 1990's; Proceedings of the ASME/JSME Pressure Vessels and Piping Conference,* Honolulu, HI, July 23-27, 1989 (A90-32362 13-39). New York, American Society of Mechanical Engineers, 1989, pp. 15–21. 10 Refs.

Experiments were carried out to establish a test method for thermal shock fracture toughness and to generate the experimental data for silicon carbide. A 20 mm wide, 50 mm long, and 6 mm thick specimen having an edge crack in the central section was heated up to a given temperature and quenched by the manner that the crack mouth side of the specimen was sunk to 1 mm depth from the water surface. The thermal shock fracture toughness of SiC was greater than the fracture toughness obtained using a three-point bending specimen at the corresponding temperature. This was well explained from the fact that the normal stress component parallel to the crack line is greater than the perpendicular stress component near the crack tip in the thermal shock specimen.

A90-31553 Fracture behavior of pitch-based carbon fiber composites with toughened epoxy resin systems. OSAMU WATANABE, SHINKICHI MURAKAMI, HIROSHI INOUE, ATSUSHI MURAKAMI, and TADATSUGU YOSHIKI, *Proceedings of the 34th International SAMPE Symposium and Exhibition,* Reno, NV, May 8–11, 1989, Book 1 (A90-31501 13-23). Covina, CA, Society for the Advancement of Material and Process Engineering, 1989, pp. 737–746. 8 Refs.

A series of toughened epoxy resin systems with different molecular weights of Bisphenol A epoxy resin oligomers has recently been proved highly effective for use in carbon fiber reinforced plastics (CFRP). The epoxy resin systems and their pitch based carbon fiber composites underwent rigorous testing to determine tensile, dynamic viscoelastic, and impact properties. Fracture surfaces were also observed under a scanning electron microscope (SEM) and optical microscope. This study also examined CTBN rubber-toughened epoxy formulations. The superior toughness of the rubber modified epoxy resin was demonstrated. It has been demonstrated that the toughness of these cured resins depends upon network density, which is directly related to molecular relaxation. Consequently, the results of this study suggest that the toughness of the matrix resin has a distinct effect on the mechanical properties of the CFRP.